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EFFECT OF NOSE SHAPE AND TAIL LENGTH ON SUPERSONIC STABILITY CHARACTERISTICS OF A PROJECTILE

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16. Abstract

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The results of the investigation showed that nose shape had no effect on the static stability. Increasing the tail length resulted in a progressively stabilizing tendency. However, only the 1.5-caliber-tail-length configuration was stable over the test angle-of-attack range at Mach number 1.5. This configuration was marginally stable or unstable at the higher Mach numbers, and the shorter configurations were unstable at all Mach numbers for either part of or the entire test angle-of-attack range.

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SUMMARY

The effect of nose shape and tail length on the static stability of a fin-stabilized projectile has been investigated in the Langley Unitary Plan wind tunnel at angles of attack to about 12° for a Mach number range from 1.5 to 2.5. The tests were made at a constant Reynolds number of 6.56×10^{6} per meter.

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INTRODUCTION

The design of missile and projectile configurations is a continuing effort which involves wind-tunnel test, flight test, and theoretical studies of various configurations. Aerodynamic lift and stabilization of these configurations is generally provided by some means of fin arrangement. Often the projectile geometry hampers the effectiveness of fins in producing a longitudinally stable configuration. Theoretical calculations are generally limited because of the large flow separation about the boattail and the angle-of-attack range and because flight-test data are expensive and difficult to interpret.

The present wind-tunnel investigation was conducted to determine the static longitudinal stability characteristics of a fin-stabilized 105-mm projectile. The model design permitted nose shape alteration and a variation in the distance between the boattail and fins from 0.5 to 1.5 calibers.

SYMBOLS

The coefficients of force and moments are referred to the body-axis system with aerodynamic moments about a point 36.373 cm (3.47 calibers) aft of the nose of each configuration. The physical quantities are given in the International System of Units (SI). (See ref. 1.) Symbols are defined as follows:

C_A axial-force coefficient, $\frac{\text{Axial force}}{q_\infty S}$

C_m pitching-moment coefficient, $\frac{\text{Pitching moment}}{q_\infty Sd}$

C_N normal-force coefficient, $\frac{\text{Normal force}}{q_\infty S}$

d reference length, model diameter, 0.105 m

M Mach number

p pressure, kilopascals

q dynamic pressure, pascals

R Reynolds number

S reference area, based on maximum diameter, 0.009 m^2

T temperature, kelvins

α angle of attack, degrees

Subscripts:

t stagnation conditions

∞ free-stream conditions

MODEL, APPARATUS, AND TEST CONDITIONS

Details of the model are presented in figure 1 and a model photograph is presented in figure 2. The test model was a 105-mm projectile with interchangeable impact and

ogive nose shapes. The tail was extended aft, increasing the distance between the boattail and the fins. In these tests, this distance was 0.5, 1.0, and 1.5 calibers.

Tests were conducted in the low Mach number test section of the Langley Unitary Plan wind tunnel, which is a variable-pressure, continuous-flow tunnel. The test section is approximately 1.2 meters square and 2.1 meters long, and the nozzle leading to the test section is of the asymmetric sliding-block type. The nozzle permits a continuous variation in the Mach number from 1.5 to 2.9.

The tests were performed at the following conditions:

M_∞	T_t, K	p_t, kPa	R
1.5	339	53.194	6.56×10^6
2.0	339	63.536	6.56
2.5	339	81.300	6.56

The angle of attack was varied from about -4° to 12° for an angle of sideslip of 0°. The dewpoint was maintained below 239 K to insure negligible condensation effects. A 0.158-cm-wide transition strip with No. 60 carborundum grains embedded in plastic was affixed 3.04 cm aft of the nose, measured along the surface, around both the impact and ogive noses. The data have been corrected for deflection of the balance and sting due to aerodynamic loads and for tunnel flow angularity. There was no base pressure correction since the model represents an unpowered projectile.

PRESENTATION OF RESULTS

The results are presented in the following figures:

DISCUSSION

The longitudinal aerodynamic characteristics for the impact-nose configuration are presented in figures 6 to 8. These results indicate an area of concern in the longitudinal stability characteristics with the assumed test center-of-gravity location at 3.47 calibers aft of the model nose. The variations of pitching moment over the test angle-of-attack range were generally nonlinear, but the linearity improved with increasing body length. At $M = 1.5$, all configurations were stable around $\alpha = 0^{\circ}$ but the angle-of-attack range for which stable conditions existed varied from about 1° for the 0.5-caliber tail position to about 6° for the 1.0-caliber position and to at least 10° for the 1.5-caliber position.

At $M = 2.0$, however, all configurations were unstable at $\alpha = 0^{\circ}$. At $M = 2.5$, the stability improved with increasing tail length although stable trim points were not achieved until about $\alpha = 14^{\circ}$ with the 0.5-caliber configuration and about $\alpha = 8^{\circ}$ with the 1.0-caliber configuration. The 1.5-caliber configuration indicated stability over the angle-of-attack range of the tests but the pitching-moment curve was nonlinear.

Typical schlieren photographs for $M = 2.5$ at $\alpha \approx 7.1^{\circ}$ for the 0.5-, the 1.0-, and the 1.5-caliber tail positions are presented in figures 3 to 5.

A comparison between results from the impact and ogive nose shapes (figs. 9 to 11) for the 1.5-caliber configuration demonstrated that the nose shape did not affect the stability. The normal-force and axial-force coefficients changed very little with Mach number or configuration.

CONCLUDING REMARKS

The effect of nose shape and tail length on the static stability of a fin-stabilized projectile has been investigated in the Langley Unitary Plan wind tunnel at angles of attack to about 12° for a Mach number range from 1.5 to 2.5. The tests were made at a constant Reynolds number of 6.56×10^{6} per meter.

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higher Mach numbers, and the shorter configurations were unstable at all Mach numbers for either part of or the entire test angle-of-attack range.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., July 16, 1973.

REFERENCE

1. Mechtly, E. A.: The International System of Units – Physical Constants and Conversion Factors (Revised). NASA SP-7012, 1969.

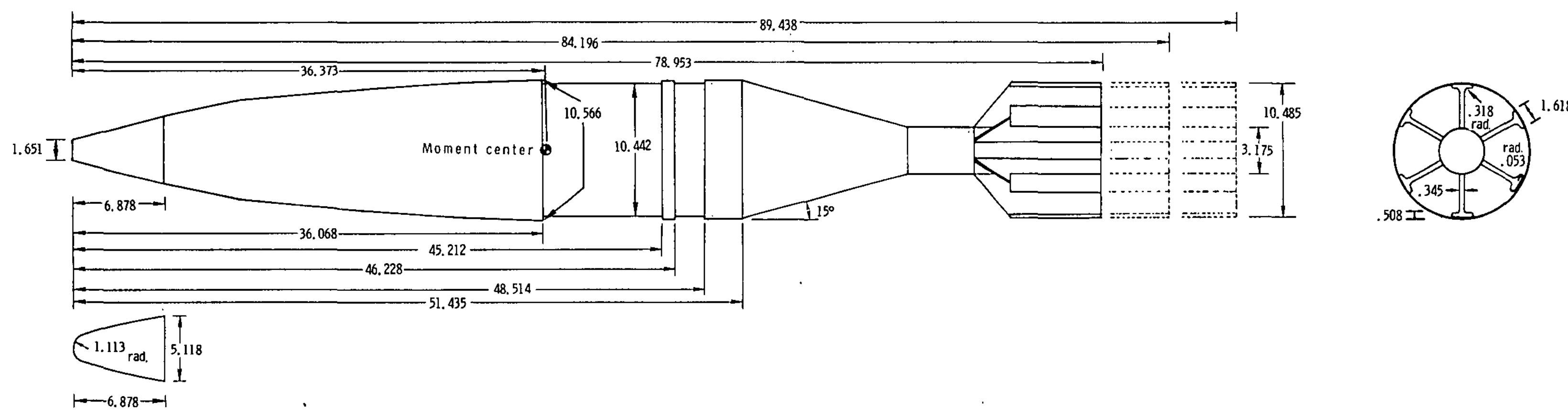

Figure 1.- Wind-tunnel model of a 105-mm projectile. (Model dimensions are in centimeters.)

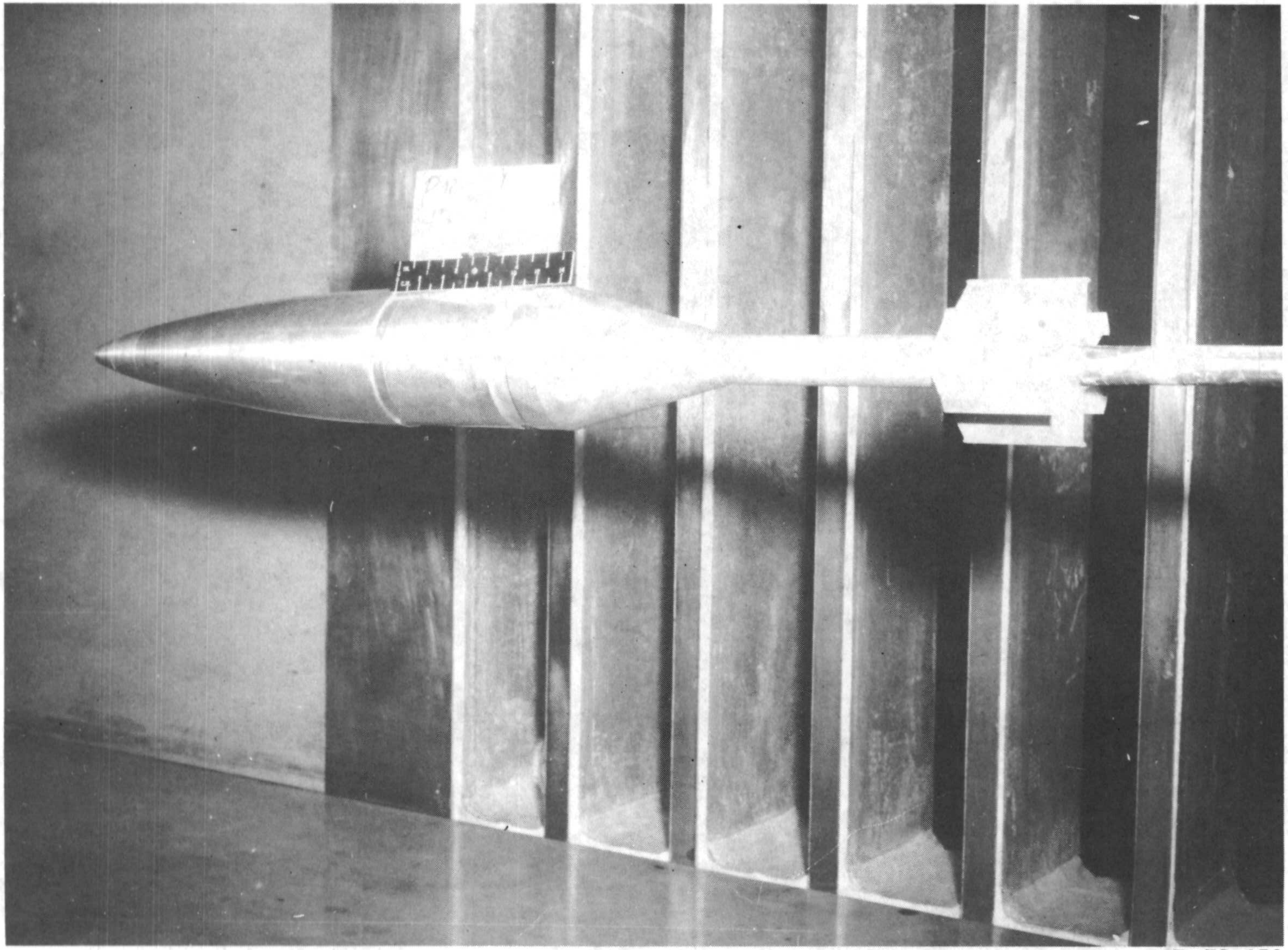

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Figure 2.- Impact-nose model with 1.5-caliber tail position.

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Figure 4.- Schlieren photograph of impact-nose model with 1.0-caliber tail position. $M = 2.5$; $\alpha = 7.05^{\circ}$.

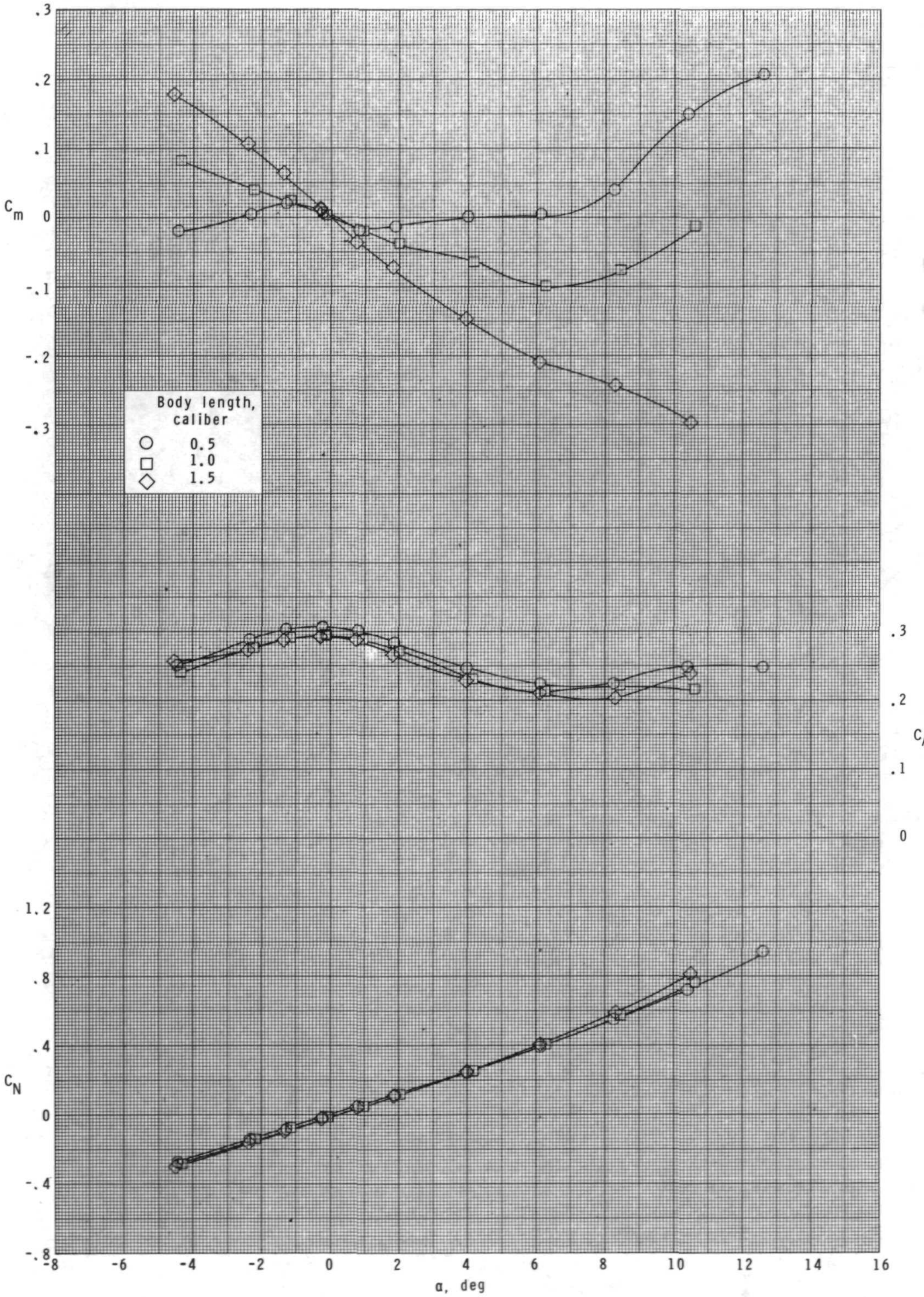

Figure 6.- Comparison of the 0.5-, 1.0-, and 1.5-caliber impact-nose configurations at M = 1.5.

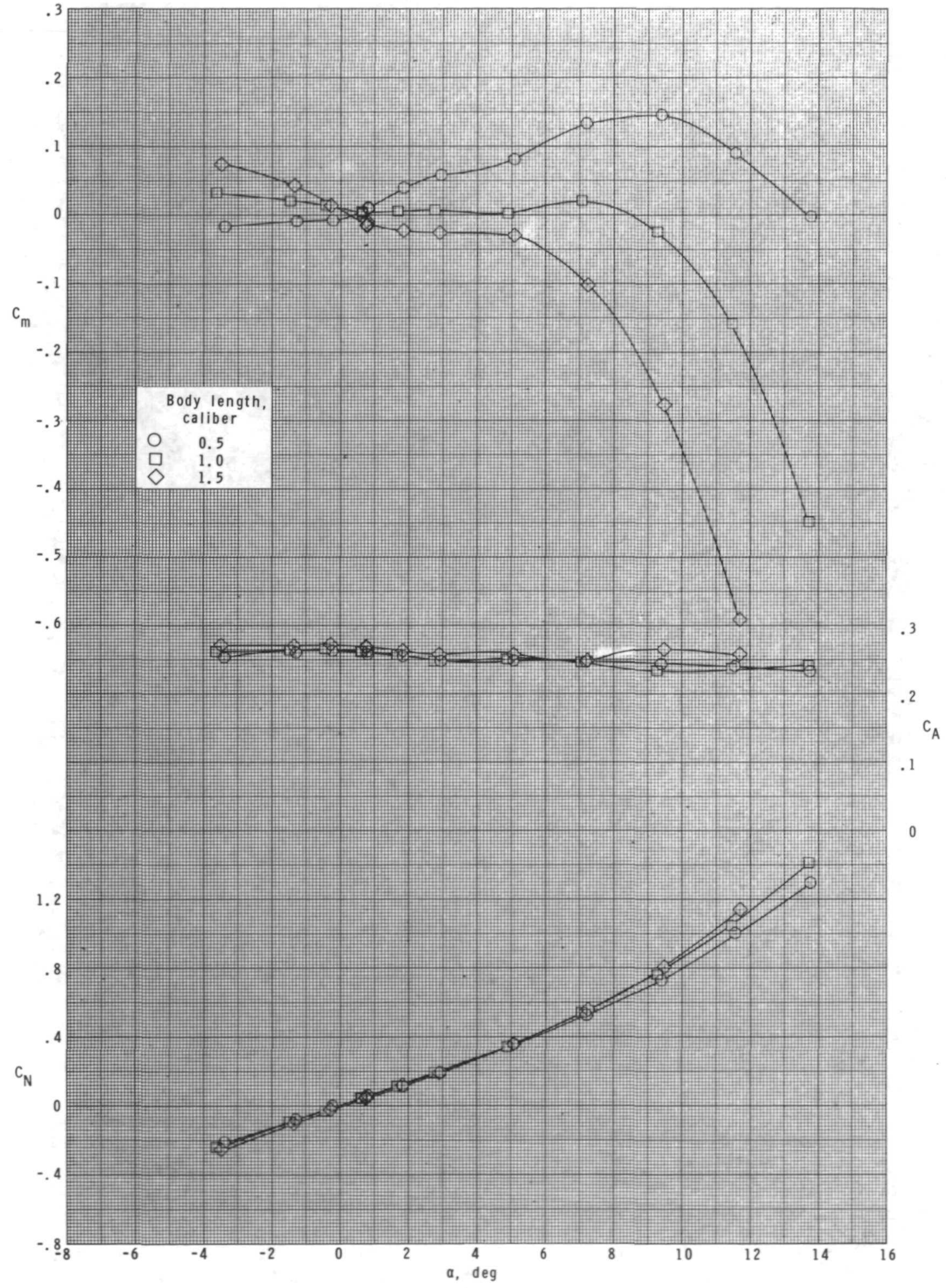

Figure 8.- Comparison of the 0.5-, 1.0-, and 1.5-caliber impact-nose configurations at $M = 2.5$.

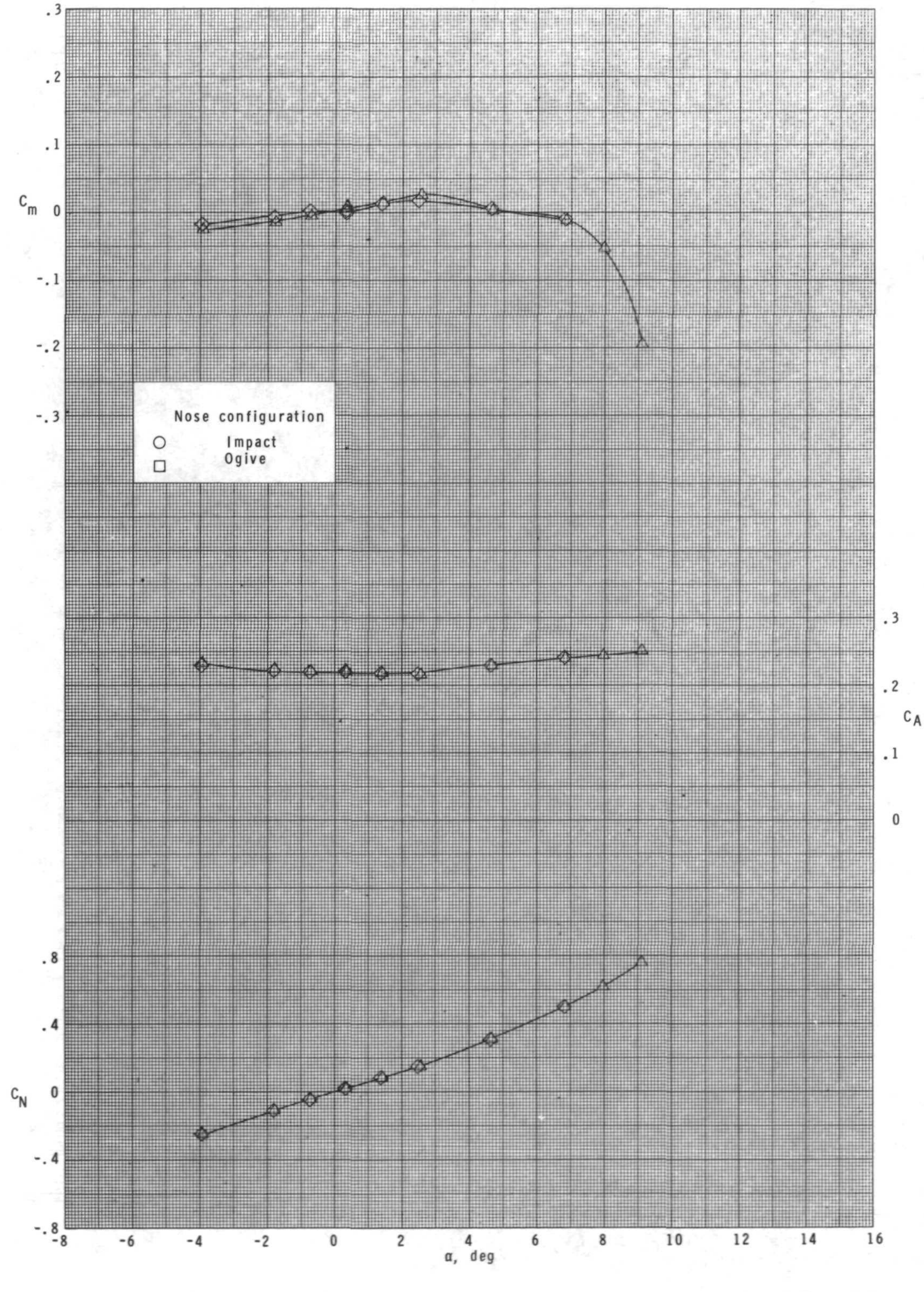

Figure 10.- Comparison of impact and ogive nose shapes for the 1.5-caliber configuration at M = 2.0.

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